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International Specialization in Research & Development

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Abstract

In this paper, I examine the effects of implementing tighter Intellectual Property Rights in a model of International Trade. In my model, firms in different countries have the choice of committing their resources to introducing new products (product innovation) or to imitating and improving upon current products (process innovation). I analyze the impact of stronger patents on innovation decisions, overall welfare and the distribution of welfare among countries. I show that, depending on parameter values, firms in developed countries (North) may altogether specialize in product innovation or may attain incomplete specialization in the sense that some innovate and some imitate. Welfare analysis will depend on the degree of specialization. In the case of incomplete specialization, tighter IPRs increase the incentives for product innovation in the North but, at the same time, increase the imitation done in the South. This finding is contrary to the conventional argument that states the reverse for imitation rates. In the case of complete specialization, stronger patents do not affect the rate of product innovation but reduce the rate of imitation, and welfare is nonmonotonic in IPRs. Finally, I examine the case of Foreign Direct Investment (FDI) and predict that stronger patents will increase the FDI while lowering the wages worldwide.

JEL Classifications: O31, O34, O38, F43

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1 Introduction

Over the last thirty years, there is an obvious trend towards the implementation of stronger Intellectual Property Rights (IPRs) worldwide. This trend started in developed world, especially in the USA after the establishment of the Federal Circuit Court of Appeals. After the collapse of the Communist Block and increasing integration of developing nations into the world economy, the USA and other developed countries have been continuously pressuring other nations to follow their lead in implementing stronger IPRs. Not only has the definition of what is patentable has broadened¹, but countries have started to harmonize with each other with regards an ever growing catalogue of products that are subject to patents².

Stronger IPRs have been one of the main topics of the Uruguay Round of trade negotiations under the World Trade Organization (WTO). As a result of these negotiations, agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) have been signed by the members of the WTO. TRIPs set minimum standards for protection of intellectual property and provides harmonization of policies between countries. Most importantly it requires National Treatment, treatment of foreign and national applicants equally as defined by the Paris Convention for the Protection of Industrial Property. Finally, thanks to the The Patent Cooperation Treaty, inventors can seek for worldwide protection since 1970s.

The main motivation behind all this policy push by developed market economies has been helping the innovators to appropriate the fruits of their labor. The idea is simple: patents create incentives for innovators at the expense of welfare costs arising from the monopolies they create. So when one compares static costs of a monopoly created by patents against dynamic benefits of more innovation you usually come up with an inverse U shaped welfare curve as a function of some measure for patent strength (Nordhaus, 1969). Recently there has been a surge in literature that questions this framework and has produced different results with regards to finding optimal patent

¹The most obvious example being software

²Many countries did not grant patents for pharmaceuticals until 30 years ago(Qian, 2007)

policy. The first problem arises from the way innovation is defined. Innovation is always thought as the act of coming up with a completely new product. But a huge portion of R&D efforts is done in order to enhance current products, by making them cheaper, or adding new features to them. This is called the case of *sequential innovation*. In this regard, stronger patents may create roadblocks for future enhancement of current products. Scholars investigated the issue of compensation for the original innovator (Scotchmer, 1996), but problem evolved into questions of how not to prevent following innovations through wrong and excessive patent rights (Bessen and Maskin, 2009). Stronger IPRs provides more protection and incentives for the first innovator but impairs the efforts of those who follow³(Scotchmer, 1996; Bessen and Maskin, 2009).

Another issue facing the analysis of IPRs is the increasing relevance of international trade and how it alters the welfare analysis conducted for a closed economy. On the one hand trade spreads the benefits of innovations across countries while making it harder for local innovators to appropriate the benefits. This encourages innovating countries to argue for stronger patents in other countries. On the other hand, there is always an incentive to impose weaker protection for foreign innovations as profits from patent granted monopolies go abroad and consumer surplus that arises from weaker protection stay within the country. This may create incentives towards implementation of weaker IPRs compared to optimum when countries act independently. This is the main argument behind harmonization of IPRs throughout the world. But the optimality of harmonization has been questioned as well and critics usually underscore that harmonization brings too much protection compared to the optimum (Grossman and Lai, 2004; Scotchmer, 2004).

This paper analyzes the effects of the implementation of stronger IPRs in context of the two issues just discussed. Innovation is the decision of allocation of resources for reaching different kind of ends: it may be about releasing a new product to markets, or it may be about enhancing current products, making them cheaper and capturing product lines (this is referred as imitation

³In their book *The Case Against Intellectual Property*, Boldrin and Levine (2008) advocate the complete removal of IPRs. They discuss the case of the steam engine and how patents actually hindered its further development and highlight the costs to the society. On the other hand Selgin and Turner (2006) provides a rebuttal for Boldrin and Levine.

in the literature). Same resources can be used for both “innovation” or “imitation”. Countries have different comparative advantages with regards to different kinds of innovations. Even though many developing market economies are putting resources into Research and Development, they are seen as failures in terms of creation of innovative economies. What is happening in fact is that these economies are not failing but specializing in certain types of R&D, defined as “Process innovations”. These are the follow up innovations to original product innovations. A Ricardian type of specialization in the world economy in types of the R&D economies conduct arises thanks to International Trade. Currently, many developing nations are creating and organizing supply chains which do not exist in the developed world and those nations are conducting research towards incremental innovations (Breznitz and Murphree, 2011). OECD reports points to this fact as “too much Development and too little Research” in case of China (OECD, 2008: 69).

In this paper I use the product cycle framework developed by Vernon (1966); Krugman (1979); Grossman and Helpman (1991b). My paper is similar to Helpman (1993)’s. But I divert from this framework by not just assuming the emergence of specialization patterns but also explaining how they emerge. For this purpose I use the framework provided by Saint-Paul (2002). This framework is rich in analyzing how resources for innovation are allocated between different kinds of research in different countries with different characteristics. In my paper innovation and imitation are not separate and one dimensional activities for firms. Firms decide on the kind of research they want to conduct, they are not bound to make only one type of research depending on their location. As a result, different patterns or degrees of specialization between countries arise. Welfare effects of stronger patent protection will be different in a world where there is a complete specialization of innovation and imitation between countries and in a world where there is incomplete specialization. In this sense I show that welfare analyses done in product cycle models are usually incomplete.

In sections two and three, I introduce the model and explain the possible equilibria and specialization patterns emerging in the world economy. I show that countries with different capacities for novel-product innovations cannot do both kinds of innovations at the same time. One country will

always completely specialize. The existence of trade exacerbates the differences between countries in terms of R&D they may conduct otherwise.

In section four, I introduce patent reforms to model. I show that depending on the kind of equilibrium an economy is in, patent reforms may have unintended results. Reforms implementing stronger IPRs usually slow down the follow-up innovator. They make it harder for the follow-up innovator to conduct research and invent around existing patents and reduce the amount of imitation in the world economy. But in our case, it may actually have an opposite effect depending on if the developed market economy has incomplete specialization. In the case of incomplete specialization, patents will induce firms in developed countries to put more resources into novel-product research. More importantly, this will allow firms in developing market economies to imitate more easily as they will have less competition in imitation and they will have more products to improve upon. Moreover patents will push countries towards more specialization. I show that increased IPRs in such a case can hurt welfare in developing countries depending on parameters chosen, but this is possible only if they hurt developed countries first. These results are contrary to standard argument that states stronger patents will decrease imitation in developing countries, will more likely to benefit developed market economies at the expense of developing countries.

In case of complete specialization in R&D between countries (the case usually analyzed in the product cycle literature), stronger patents may not have any impact on the rate of novel-good innovation at all, yet they will alter the welfare distribution. Unlike the previous case, here I show that tighter IPRs don't increase the innovation, but will decrease the imitation. For a range of parameter values I show that tighter IPRs increase welfare in developed countries, but reduce overall welfare by reducing the welfare in the developing market economies. Policy implications contrast sharply between complete and incomplete specialization cases.

Then I discuss the difficulties that a developing market economy faces in promoting Product innovation through subsidies.

Finally the last part of the paper introduces Foreign Direct investment by multinational firms

and allows us to see how multinational firms react to different IPRs regimes and how they change their investment decisions accordingly.

2 Model

I consider a world economy with two freely trading countries and a continuum of industries indexed by $j \in [0, N_t]$, N_t being the number (measure) of variety of goods available at each instant of time t . The model is based on Saint-Paul (2002) model. Each good is provided by one company who act as monopoly and each firm is only providing one good.

There are two types of innovation activity; “*Product Innovation*” and “*Process Innovation*”. Former is the action of introducing a novel product that was not being produced before and latter consists of making the production of a novel product more efficient. Two countries are differentiated by their capacity in terms of their product innovation; “*North*” being more capable of introducing novel products, *i.e.* their product innovation rate per researcher is higher than “*South*”.

2.1 Households

Households worldwide share an identical preferences for differentiated products. Their welfare equals the discounted flow of instantaneous utility $u(t)$:

$$U = \int_0^{\infty} e^{-\rho t} \ln u(t) dt \quad (1)$$

The static utility function takes the classic Dixit and Stiglitz (1977) form:

$$u(t) = \left(\int_0^{N_t} c(j, t)^\alpha dj \right)^{1/\alpha}, 0 < \alpha < 1 \quad (2)$$

In (2) $c(j, t)$ denotes amount of differentiated product j that household consumes. N_t represents the number (measure) of varieties available on the market at time t .

The representative household maximizes (1) subject to the following budget constraint:

$$\int_0^{\infty} e^{-R(t)} X(t) dt \leq \int_0^{\infty} e^{-R(t)} Y(t) dt + A(0) \quad (3)$$

where $X(t)$ and $Y(t)$ are the individual flow of spending and income at time t , $A(0)$ is the value of assets households held at time zero and $R(t) = \int_0^t r(s) ds$ is the cumulative interest rate. I assume there is free international capital flow and same interest rates prevail in both countries at all times.

The solution to inter-temporal maximization problem gives us:

$$\frac{\dot{X}(t)}{X(t)} = r(t) - \rho \quad (4)$$

The allocation of expenditure across products at each point in time gives us the instantaneous demand for variety j :

$$c(j, t) = \frac{p(j, t)^{-\sigma}}{\int_0^{N_t} p(i, t)^{1-\sigma} di} X(t) \quad (5)$$

where $p(j, t)$ is the price of variety j at the time t and $\sigma = \frac{1}{1-\alpha}$ is the elasticity of substitution. We'll define a world price index as:

$$P = \int_0^{N_t} p(i, t)^{1-\sigma} di$$

and normalize it to 1 for each time period t . Household income consist of wages they earn and profits they acquire from firms as they are the owners of the firms.

Since we have normalized the overall price level to one at all times, we obtain the indirect utility function

$$\ln u(t) = \ln X(t) - \ln P(t) = \ln X(t) \quad (6)$$

Instantaneous utility function is equal to spending at each period.

2.2 Innovation and Manufacturing Technologies

Labor is the only factor of production for both manufacturing and innovation. Both *North* and *South* have a measure of 1 labor, out of which z_i are researchers and $1 - z_i$ are manufacturing workers. There are two types of innovation that can be undertaken by researchers; *product innovation* which results in creation of blueprints for *primary goods* that did not exist before (same as in Grossman and Helpman (1991b)) and *process innovation* which involves introduction of *secondary goods* which are improvements upon *primary goods*. Secondary goods are cheaper to produce and eventually replace primary goods in the market. From customers' perspective there is no difference if they consume primary or secondary goods; they receive the same utility from consumption of same quantities.

As a result, goods have two stages in their manufacturing cycle, first they are produced as primary goods and production of each unit of primary good requires 1 unit of labor. Later they are exposed to further improvements in form of process innovation and I call them as secondary goods afterwards. A unit of secondary good requires λ units of labor to be produced, where $\lambda < 1$. Goods can be improved only once. Finally goods are going to be obsolete at a rate of δ . Both secondary and primary goods get to be obsolete at the same rate. As a result, some primary goods do not get to be improved upon before they become obsolete.

Let z_{i1} indicate number of researchers working for product innovations in country i , whereas z_{i2} indicates number of workers working for process innovation. We define $z_1 = z_{N1} + z_{S1}$ as the total number of product innovators globally, and $z_2 = z_{N2} + z_{S2}$ as the total number of process innovators globally.

Similarly, let n_{i1} denote the number of primary goods being produced in country i , and n_{i2} indicates number of secondary goods. $n_i = n_{i1} + n_{i2}$ is the number of goods produced in each country i , and $n_1 = n_{N1} + n_{S1}$ is the number of primary goods available to customers. $n_2 = n_{N2} + n_{S2}$ is the number of secondary goods. There is free trade; every type of good is being offered to customers without any trade costs. At each point in time t , $n_N(t) + n_S(t) = n_1(t) + n_2(t) = N_t$.

2.2.1 Product Innovation

One unit of researcher in country i creates $\gamma_i dt$ amount of novel goods if they work dt amount of time. By assumption $\gamma_N > \gamma_S$, that does not necessarily mean that researchers in North are more capable with coming up with new ideas. It says researchers doing product innovation in North are able to transform the novel ideas they come up with into actual products more rapidly. This difference between countries arises mainly due to differences in institutional arrangements. One such difference may arise in how such innovations are financed. As we will see, product innovation is a more risky business compared to process innovation. Lack of a capable capital market that can utilize sources like venture capital to finance risky innovations properly can contribute to such a gap (Orman, 2008).

In any case, the reason for gap between two countries' primary innovation capabilities is beyond the scope of this paper. Once a primary product is innovated, its manufacturer gains the monopoly rights to it, and sell it until its product is replaced by a secondary innovation or becomes obsolete.

2.2.2 Process Innovation

Process innovation is described through a matching function the way it is described Saint-Paul (2002), inspired from job matching functions from labor literature (Pissarides (2000)). Researchers can improve upon any good on the market regardless of the origin of the good or researcher. In a state where there are z_2 amount of process innovation researchers working on n_1 number of primary innovations, there are \mathcal{M} number of matchings (successes), where \mathcal{M} is found via a matching function M :

$$\mathcal{M} = M(n_1, z_2) = \frac{(z_2)^\alpha (n_1)^{1-\alpha}}{m} \quad (7)$$

This function represents the congestion and decreasing returns that arise when there is increasing number of secondary innovation researchers.⁴ This matching function is a generalized version

⁴In Acemoglu and Cao (2010), same idea of congestion arises and they explain it as a result of “fishing in the same pond; replication of ideas and efforts by different researchers”.

of innovation functions used in Grossman and Helpman (1991a) where α was taken equal to 0, or Helpman (1993) where α was taken equal to 1. One crucial aspect of this paper will be to capture the process of decision of allocating resources on different kinds of innovations. As a result z_2 is a variable needs to be taken into account. And just like in Helpman (1993), number of novel goods n_1 is also a factor that affects rate of replacement (imitation) of primary goods that needs to be taken into account: Matching function captures positive spillover effect of a higher n_1 for process innovation, while decreasing returns to higher numbers of process researchers, z_2 . A very low number of primary goods would mean very low returns to process innovation.

Variable m captures the idea of frictions arise that process innovators face. More strongly enforced and more broadly defined patents increases m in this model⁵. One interpretation for this is that patents is making it harder for followers to imitate and come up with improvements upon new products. It will be harder for secondary innovators to “invent around” the patented product stronger the patents are. This is in line with the literature concerning sequential innovations. A stronger patent makes it harder for others to follow up with improvements for the same good (Bessen and Maskin, 2009; Hopenhayn et al., 2006). In this sense, stronger patent systems are implemented to divert more resources to introduction of novel goods.

A researcher can create κdt number of secondary goods if they work dt amount of time. κ is the arrival rate of secondary innovation that is endogenously determined within the system via matching function M . Likewise we define the rate of replacement of primary goods through process innovation as ν . We derive the values for κ and ν as follows:

$$\begin{aligned}\kappa &= \frac{M(n_1, z_2)}{z_2} = \frac{1}{m} \left(\frac{n_1}{z_2} \right)^{1-\alpha} \\ \nu &= \frac{M(n_1, z_2)}{n_1} = \frac{1}{m} \left(\frac{n_1}{z_2} \right)^{-\alpha}\end{aligned}\tag{8}$$

As a result of the structure of matching function, we have a mechanic relationship between κ

⁵This is similar to Helpman (1993), where tighter IPRs basically increased the friction to imitation

and ν expressed by what we will refer as *matching frontier* throughout paper:

$$(m\kappa)^{1/(1-\alpha)} = (m\nu)^{1/(-\alpha)} \quad (9)$$

I assume that countries synchronize their patent system, enforce the same level of protection. They also provide national treatment, which is a requirement of TRIPs⁶ agreement that was negotiated during Uruguay rounds. National treatment prevents countries to discriminate against foreign goods when it comes to intellectual property rights protection (World Intellectual Property Organization, 1968: 223-224).

Finally I assume that secondary good producers have monopoly powers as well. Secondary good producers do not have to compete with each other as it is not profitable to spend resources to improve the same primary good and get zero profits. I assume that λ is significantly small that the secondary good producers are able to charge limit monopoly price and drive the primary good producers out of the market. We can also think that secondary goods producers are also receiving a patent, hence ensuring their monopoly rights and avoiding a Bertrand competition with primary good producers.

2.2.3 Law of Motion for Variety of Goods

Finally let us sum the law of motions for the number of products available in the market:

$$\begin{aligned} \frac{\partial n_1}{\partial t} &= -(\delta + \nu) n_1 + \gamma_N z_{N1} + \gamma_S z_{S1} \\ \frac{\partial n_2}{\partial t} &= -\delta n_2 + \nu n_1 = -\delta n_2 + \kappa z_2 \\ \frac{\partial N}{\partial t} &= -\delta(n_1 + n_2) + \gamma_N z_{N1} + \gamma_S z_{S1} \end{aligned} \quad (10)$$

Figure (1) represents flow rates for each type of good. At a steady state equilibrium number of goods are stable, *i.e.* $\frac{\partial n_1}{\partial t} = 0$, $\frac{\partial n_2}{\partial t} = 0$ and $\frac{\partial N}{\partial t} = 0$. One thing to note here is that, at a steady

⁶Trade-Related Aspects of Intellectual Property Rights

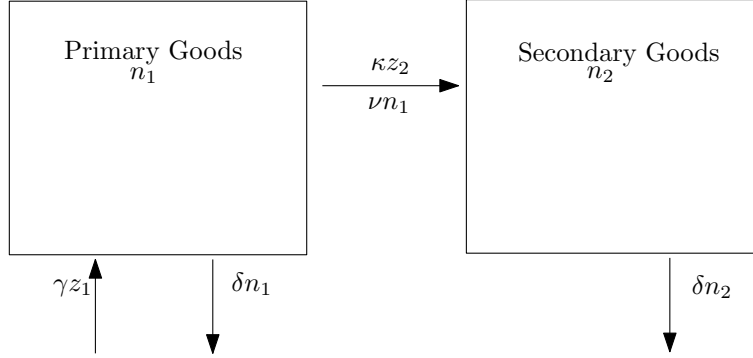


Figure 1: Law of Motion for Goods

state equilibrium total number of goods N depends only on the number of product innovators z_{i1} allocated by each country i . At a steady state, $N = \frac{\gamma_N z_{N1} + \gamma_S z_{S1}}{\delta}$.

3 Market Equilibrium

We will be looking at the steady state equilibria only.

3.1 Prices and Wages

Taking into account demand function for a firm's product that was given by (5), and the fact that we normalized world price index to one, we get the demand equation $c_j = X p_j^{-\sigma}$, where X is the total world expenditure on goods (We'll indicate spending in North and South as X_N and X_S respectively). Since firms are acting as monopolies on goods they provide, their pricing decisions can be summarized as:

$$p_j = \begin{cases} \mu w_i & \text{if } \textit{primary} \text{ good} \\ \mu \lambda w_i & \text{if } \textit{secondary} \text{ good} \end{cases} \quad \text{for } i = N, S \quad (11)$$

where w_i is the manufacturing wage rate in country i , and μ is the monopoly mark-up over per unit cost of goods, with $\mu = \sigma / (\sigma - 1)$. Compensation for researchers in country i is indicated by

f_i . Then the flow of profits for manufacturer who is producing *primary* goods in country i is given by:

$$\pi_{i1} = (\mu - 1) X w_i^{1-\sigma} \mu^{-\sigma} \quad (12)$$

whereas for secondary good producer it is:

$$\pi_{i2} = (\mu - 1) X (\lambda w_i)^{1-\sigma} \mu^{-\sigma} \quad (13)$$

3.2 Earnings and Costs of a Firm

Net present value of expected earnings V are determined by the following functions for primary and secondary goods manufacturers:

$$rV_{i1} = \pi_{i1} - (\delta + \nu) V_{i1}$$

$$rV_{i2} = \pi_{i2} - (\delta) V_{i2}$$

for $i = N, S$. From which we find that:

$$\begin{aligned} V_{i1} &= \frac{(\mu - 1) X w_i^{1-\sigma} \mu^{-\sigma}}{r + \delta + \nu} \\ V_{i2} &= \frac{(\mu - 1) X (\lambda w_i)^{1-\sigma} \mu^{-\sigma}}{r + \delta} \end{aligned} \quad (14)$$

The cost of creating a blueprint for a *primary* good in country i is $F_{i1} = \frac{f_i}{\gamma_i}$, whereas cost of replacing a *primary* good with a *secondary* good is given by $F_{i2} = \frac{f_i}{\kappa}$.

3.3 Finding the Equilibrium

3.3.1 Closed Economy

In order to talk about an equilibrium in a world where we have trade, we first describe an equilibrium in a closed economy. We can use the same notation but just dropping the notations

for countries.

In a closed economy, value V of a firm has to be equal to cost of R&D of either *product* and *process* innovations, depending kind of good it is. As a result the conditions $F_1 = V_1$ and $F_2 = V_2$ need to be satisfied. This is a result of free entry assumption on the markets. If blueprints are too cheap for either kind of goods ($F_1 < V_1$ or $F_2 < V_2$), demand for the researchers will go up, driving the wages f up. Likewise cost of blueprints F can not exceed expected earnings V , some of the prospective manufacturers will leave the market. If we define $RR = \frac{V_1/F_1}{V_2/F_2}$, then we get:

$$RR = \frac{\lambda^{\sigma-1} (r + \delta) \gamma}{\kappa (r + \nu + \delta)} \quad (15)$$

The free entry assumption in a closed economy requires $RR = 1$. $RR = 1$ curve gives us values for (ν, κ) where $\frac{V_1/F_1}{V_2/F_2} = 1$.

Using $RR = 1$ and matching frontier equation (9), we find the equilibrium κ and ν values in this economy. Then using equilibrium (ν, κ) values from this economy, we can find prices, wages and earnings (p, w, f, X) that bring this economy to equilibrium and allows us to solve for the equilibrium allocations⁷. Such an equilibrium is illustrated in figure 2. In figure 2, if you pick a pair of values (ν, κ) above RR line, then $RR < 1$, implying $V_1/F_1 < V_2/F_2$. In this case process innovation is more profitable, and no product innovation is done. Similarly for any point below RR curve, we have only product innovation in this economy, which contradicts with the fact that (ν, κ) being nonzero (there has to be some process innovation going on). At equilibrium, both happen as both will have to be equally profitable and we will be on RR curve.

3.3.2 Open Economy

In an open economy, we have a more complicated situation. There are three possible scenarios:

1. North is doing both *process* and *product* innovation, South is specialized in *process* innovation

⁷For each (ν, κ) value picked on $RR = 1$ we can find an equilibrium price vector (p, w, f) that ensures not only the condition $RR = 1$, but also $V_1/F_1 = V_2/F_2 = 1$. On other points of RR , the $V_1/F_1 = V_2/F_2$ equilibrium will still hold for said prices, but we will lose the last part of the equilibrium; earnings to cost ratio will not be equal to one.

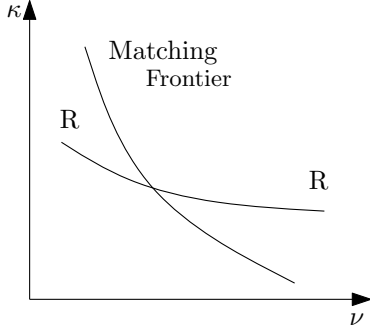


Figure 2: Closed Economy Equilibrium

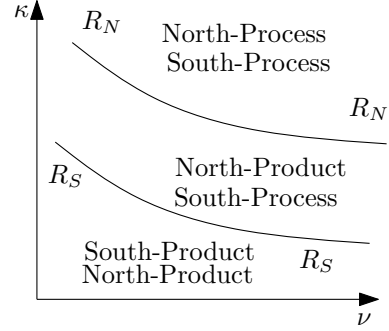


Figure 3: Innovation Regimes

2. North is specialized in *product* innovation, South is doing both *process* and *product* innovation
3. North is specialized in *product* innovation, South is specialized in *process* innovation

The reason for that is, RR_N lies above RR_S on the plane of (ν, κ) . Therefore *process* innovation is always relatively more profitable in South compared to North for any given values of (ν, κ) . Whenever South is doing *product* innovation, that necessarily implies North is also doing *product* innovation. The result we get is that we won't have a case where both countries doing both types of innovations (or a case where South is specialized in product innovation whereas North is specialized on process innovation). Figure 3 describes the innovation regimes for countries. Countries will be doing both kinds of innovations when equilibrium is on their respective RR curves. And they will do the kind of research they are assigned when equilibrium is in the indicated zones on the given figure. But of course some of the innovation zones on that figure are not supported by any possible equilibrium.

The equilibrium of this system lies on either RR_N , RR_S , or the region that lies in between. First one correspond to scenario 1, second one correspond scenario 2, and last one correspond to scenario 3. It can't lie above RR_N as someone has to do some product innovation or we won't have any goods in this economy, or below RR_S since then it implies there is no secondary innovation. This contradicts with the fact that (ν, κ) having positive values. Besides, looking at the matching function, we see that we have the *Inada Conditions* being satisfied for the process innovations, *i.e.*

the return for the process innovation go to infinity as the number of process innovators go to zero:

$$\lim_{z_2 \rightarrow 0} \frac{\partial M(n_1, z_2)}{\partial z_2} = +\infty$$

Aside from RR_N , RR_S and *matching frontier* itself, we'll need one more condition to locate the equilibrium (ν, κ) . We need to be more specific about possible equilibrium points in full specialization case. For this, we look at the flow rates for goods. At full specialization all southern researchers are process innovators and all northern researchers are product innovators. From the law of motion equation (10) and steady state condition for primary products, we get:

$$0 = -(\delta + \nu) n_1 + \gamma_N z_1$$

Then from (8), we get $\kappa z_2 = \nu n_1$. Number of process innovations done by researchers are equal to number of primary goods being replaced by secondary goods. Combining these two equations gives us $\kappa = \frac{\nu \gamma_N}{\delta + \nu} \frac{z_1}{z_2}$. Finally using the fact that at full specialization $z_1 = z_N$ and $z_2 = z_S$, we have the *specialization condition*:

$$\kappa = \frac{\nu \gamma_N}{\delta + \nu} \frac{z_N}{z_S} \quad (16)$$

This is a positive sloped line on (ν, κ) plane as can be seen on figure (4) as *SS* line. When countries fully specialize, equilibrium (ν, κ) values have to lie on this line. Any (ν, κ) values lying above this line indicates a situation where $z_1/z_2 > z_N/z_S$, which is the case that some researchers from South is doing product innovation. Similarly any (ν, κ) values lying below this line indicates a situation where $z_1/z_2 < z_N/z_S$, which is the case that some researchers from North is doing process innovation.

Now we can define the equilibrium locus of this economy. It can be seen from figure (4). It is the bold line segment, labeled as "*ABCD*" on the graph.

The equilibrium on the world economy determined by line segment *ABCD* and *matching frontier*. There are three possible scenarios depending on where matching frontier and equilibrium line

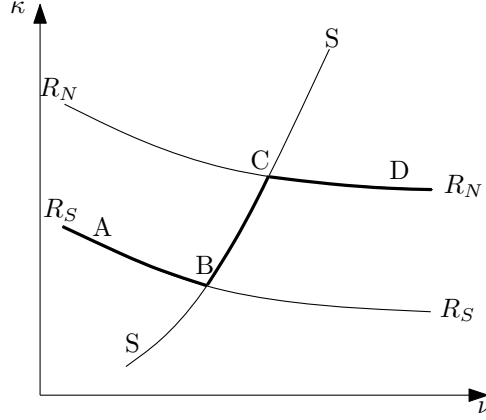


Figure 4: Equilibrium Locus

intersect with each other. Economy may be fully specialized and be on SS curve (on CB segment of equilibrium line). Or there are both types of innovations being conducted by South while North is specialized on Product innovation. In this case world economy is above SS curve as indicated, and since South will be doing both product and process innovation, both activities have to be equally profitable in South hence economy has to be on part of RR_S curve that is above SS (on AB segment of equilibrium line). Finally there may be both types of innovations being conducted by North while South is specialized on Process innovation. In this case world economy is below SS curve, and since North will be doing both product and process innovation, both activities have to be equally profitable in North hence economy has to be on part of RR_N curve that is below SS curve (on CD segment of equilibrium line).

General Equilibrium

Finally we can quickly define a steady state general equilibrium for this economy. :

For $i = N, S$, given the prices and wages $\left\{ \{p_j\}_{j=0}^{N=n_1+n_2}, w_i, f_i \right\}$, total expenditures $\{X_i\}$, distribution of variety for *primary* and *secondary* goods $\{n_{i1}, n_{i2}\}$, distribution of researchers $\{z_{i1}, z_{i2}\}$, flow rates $\{\kappa, \nu\}$; equilibrium allocation $\{c_j\}_{j=0}^{N=n_1+n_2}$ will:

- solve the Household maximization problem:

- maximize the producers' profits $\pi_j \forall j$,

while

- Number of goods are stationary:

$$\gamma_N z_{N1} + \gamma_S z_{S1} = (\delta + \nu) n_1$$

$$\kappa z_2 = \nu n_1 = \delta n_2$$

- Cost of creating a blue print for primary and secondary products are equal to their expected lifetime profits,
- The following equations hold for production, spending and general price level

$$1 - z_N = n_{N1} c_{N1} + n_{N2} c_{N2} \lambda$$

$$1 - z_S = n_{S1} c_{S1} + n_{S2} c_{S2} \lambda \tag{17}$$

$$X = p_{N1} n_{N1} c_{N1} + p_{N2} n_{N2} c_{N2} + p_{S1} n_{S1} c_{S1} + p_{S2} n_{S2} c_{S2}$$

$$P = 1 = p_{N1}^{1-\sigma} n_{N1} + p_{N2}^{1-\sigma} n_{N2} + p_{S1}^{1-\sigma} n_{S1} + p_{S2}^{1-\sigma} n_{S2}$$

where c_{i1} and c_{i2} represents the amount each *primary* and *secondary* good being produced in country $i = N, S$, and p_{i1} , p_{i2} are their respective prices.

Full Specialization Case

World is in a full North-Product Innovation and South-Process Innovation equilibrium depicted in many product cycle models such as Vernon (1966), Krugman (1979) and Grossman and Helpman (1991b). This particular equilibrium is depicted in figure (5) in our framework. In this case we have $c_{N2} = c_{S1} = z_{N2} = z_{S1} = 0$.

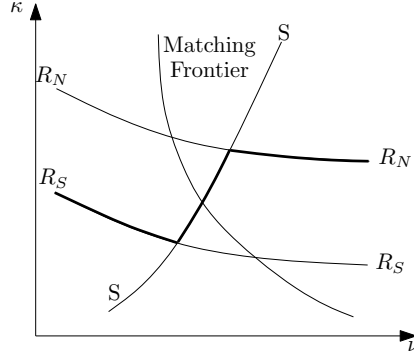


Figure 5: Full Specialization Equilibrium

4 Stronger Patents

Now we can look at effects of certain policy changes, especially changes in patent policy. In this model, stricter patent policies are conducted through increasing the variable m in matching function \mathcal{M} . The idea is that, stronger patent policies make it harder for process innovators and imitators to introduce secondary products to the market. It is a friction introduced in the system to divert more resources to product innovation. It is informative to look at the case of closed economy first to see how patent policy is conducted within this framework, results of such policies. Then we will switch to open economy case.

4.1 Closed Economy

In a closed economy, patents always divert more resources from process to product innovation. A stronger patent system make product innovations relatively more profitable at the expense of making it harder for follow up innovations to capitalize on their improvements. Stronger patent protection shifts the *matching frontier* left.

In the new equilibrium after the reform, number of process innovators z_2 declines, and number of product innovators z_1 increases⁸. Less process innovators mean a higher return per process

⁸To see why this is the case, suppose reverse is true. But then, unlike what happens on figure 6, return per process innovator κ would have to decrease as a result of higher number of process innovators z_2 , lower number of primary goods n_1 and congestion this situation would create. For more formal proof of results I mention in this part,

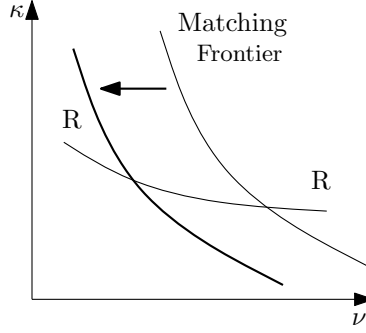


Figure 6: Patent Reform in a Closed Economy

innovator, *i.e.* an increase in κ , despite the existence of stronger patents. As implied by equation (10) total variety of goods N and number of primary goods n_1 always increases. The effect on n_2 is ambiguous. But we can say that as long as κ is not too low, it decreases.

The effects on welfare is a little more complicated as expected. Using manufacturing constraint, price normalization equations:

$$1 - z = n_1 c_1 + n_2 c_2 \lambda$$

$$P = 1 = p_1 n_1 + p_2 n_2$$

and inserting equilibrium prices and demand functions (equations 5 and 11) we get the equilibrium values for wages and total income/expenditure:

$$\begin{aligned} w &= (n_1 + n_2 \lambda^{1-\sigma})^{\frac{1}{\sigma-1}} \frac{1}{\mu} \\ X &= (n_1 + n_2 \lambda^{1-\sigma})^{\frac{1}{\sigma-1}} (1 - z) \end{aligned} \tag{18}$$

It can easily be seen that welfare depend on variety of goods as well as amount of consumption. If the gains from process innovations is not big enough (*ie.* λ is not small enough), stronger patents

please refer to Appendix

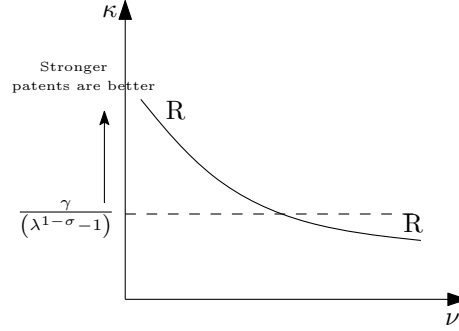


Figure 7: Welfare Effects of Patent Reform

increase the total variety and improve welfare.

As we know now, increasing patent protection increases the rate of improvement per process innovator (κ) while decreasing the probability of being replaced by a secondary good for primary goods(ν). This two rates have different effects on total welfare X . Increasing κ as a result of stricter patent laws always improves welfare, on the other hand effects of change in ν is less certain⁹. Stronger patents improve welfare through ν as well as κ only when $\frac{\partial X}{\partial \nu} < 0$. Solving the model tells us that $\frac{\partial X}{\partial \nu} < 0$ iff $\kappa > \frac{\gamma}{(\lambda^{1-\sigma}-1)}$. Below the cut point of $\kappa = \frac{\gamma}{(\lambda^{1-\sigma}-1)}$, stronger patent laws' effects on κ and ν work against each other. But above the cut point, stronger patents always contribute positively to welfare (see figure (7)).

In an economy with low enough product cycle rate ν or high enough κ , stronger patents lead the economy to a higher level of welfare. It is easier to make a case for stronger patents in such an economy.

4.2 Open Economy

In an open economy effects of a patent reform that implements stronger protection for primary goods are more complicated. If South is specialized on process innovation completely, then North is either doing both kinds of innovation or specialized on product innovation. Results of implementation of stronger patents to protect product innovation being done in North depend on if North

⁹In this economy, after all we have $\frac{\partial \kappa}{\partial m} > 0$ and $\frac{\partial \nu}{\partial m} < 0$ as can be seen on figure 6

is completely specialized like South.

4.2.1 Incomplete Specialization

If the economy is at equilibrium on CD part of equilibrium line on figure 4, then North is doing both kinds of innovations. We can find how much North is allocating towards each type of innovation in terms of (ν, κ) and other given parameters of the economy using flow equations $\kappa z_2 = \nu n_1$, $n_1(\delta + \nu) = \gamma z_1$ and $z_1 + z_2 = z_N + z_S$ ¹⁰. The allocation of researchers determine the number of goods being produced in both regions (n_{N1}, n_{N2} and n_{S2}).

Finding the distribution of goods between regions allows us to solve for the welfare and wage values for countries. Modifying equation (17), we get the relevant equations to solve for X , w_N and w_S :

$$\begin{aligned} 1 - z_S &= n_{S2} c_{S2} \lambda \\ 1 - z_N &= n_{N1} c_{N1} + n_{N2} c_{N2} \lambda \\ 1 &= p_{N1}^{1-\sigma} n_{N1} + p_{N2}^{1-\sigma} n_{N2} + p_{S2}^{1-\sigma} n_{S2} \end{aligned}$$

where values for price(p) and demand for goods(c) can be expressed in terms of manufacturing wages and total welfare through equations (5) and (11). Then we get the following system of equations:

$$\begin{aligned} 1 - z_S &= n_{S2} X \lambda^{1-\sigma} (\mu w_S)^{-\sigma} \\ 1 - z_N &= n_{N1} X (\mu w_N)^{-\sigma} + n_{N2} X \lambda^{1-\sigma} (\mu w_N)^{-\sigma} \\ 1 &= (\mu w_N)^{1-\sigma} n_{N1} + (\mu \lambda w_N)^{1-\sigma} n_{N2} + (\mu \lambda w_S)^{1-\sigma} n_{S2} \end{aligned}$$

¹⁰I will assume $z_N = z_S = z$ for simplicity. Also in this case $z_1 = z_{N1}$, $z_{S2} = z_S$, and $z_{N1} + z_{N2} = z_N$. A complete solution is provided in Appendix

Finally solving for X, w_N and w_S we find the following values:

$$\begin{aligned}
X &= (1 - z) \left[(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma} + (n_{S2}\lambda^{1-\sigma})^{1/\sigma} \right]^{\sigma/(\sigma-1)} \\
w_N &= \left[(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma} + (n_{S2}\lambda^{1-\sigma})^{1/\sigma} \right]^{1/(\sigma-1)} (n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma} \\
w_S &= \left[(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma} + (n_{S2}\lambda^{1-\sigma})^{1/\sigma} \right]^{1/(\sigma-1)} (n_{S2}\lambda^{1-\sigma})^{1/\sigma}
\end{aligned} \tag{19}$$

Welfare and wages are monotonically increasing in number of goods being produced (n_{N1}, n_{N2} and n_{S2}). We will call $(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma}$ as the Northern contribution to welfare, and $(n_{S2}\lambda^{1-\sigma})^{1/\sigma}$ as the Southern contribution.

Stronger patent protection pushes North towards committing more resources on product innovation and less on process innovation¹¹. Even though stronger patents are introduced to increase the *friction* for process innovators, κ -return per process innovator- increases in this economy. This happens because there will be less competition among imitators as patents get stronger. Researchers in Northern countries will flock to product innovation as they will receive more protection and increase the number of goods to be improved upon, leaving more fish in the pond with less fishermen for other process innovators. This can be seen from figure 4, where economy is moving along the CD part of equilibrium as patents get stronger, ν declining while κ increasing.

We can provide following proposition on distribution of production between countries, which will become crucial when we analyze welfare implications of stronger patents:

Proposition. n_{N1}, n_{S2} and N are monotonically increasing with stronger patent protection, whereas n_{N2} is monotonically decreasing. n_2 is an inverse U shaped function of patent protection. It will increase up to some level of protection, but then decline.

Since South is completely specialized on process innovation on CD part of equilibrium line, return per process innovator in South increases as long as equilibrium does not move to the zone where North also completely specialize. The conclusion we get in this case is that even though

¹¹As m increases, ν declines. Effects of this change on distribution of goods and researchers is shown in Appendix.

stronger patents are implemented in South as well as North, not only South does not start doing any product innovation, but also number of goods being imitated per instance of time (κz_S) increases in South, as well as the number of products ($n_{S2} = \frac{\kappa z_S}{\delta}$) being produced in South.

Number of primary goods introduced to market per instance of time ($\gamma_N z_{N1}$) increases as a result of more product innovation being done in North, causing an increase in $n_1 = \frac{\gamma_N}{(\delta + \nu)} z_{N1}$. A higher n_1 means more goods to work on for process innovators. These two effects overcome the negative effect of increase in matching friction m . On the contrary, as z_{N1} increases, z_{N2} and n_{N2} monotonically declines. Total number of secondary goods ($n_2 = n_{S2} + n_{N2}$) being produced in this economy is an inverse u shaped function of patent strength m , it increases up to some level of protection, but then it declines.

Stronger patents increase the resources allocated on product innovation, and increase the total number of goods available to consumers. In this specific case, from equation (10), we know that $N = \frac{\gamma_N z_{N1}}{\delta}$. As z_{N1} increases as a result of stronger patents, total number of variety of goods also increases in this economy.

Proposition. n_{N1}, n_{S2} and N are monotonically increasing with stronger patent protection, whereas n_{N2} is monotonically decreasing. n_2 is an inverse U shaped function of patent protection. It will increase up to some level of protection, but then decline.

Looking at the welfare equations (19), we see that contributions of n_{N1} and n_{S2} to total welfare are both positive as they increase as a result of stronger IPR protection, whereas declining n_{N2} has a negative contribution. A loss in total welfare is only possible if losses from a decline in n_{N2} overcome the gains from both n_{N1} and n_{S2} . In such a scenario declining n_2 not only decreases the Northern contribution to welfare $(n_{N1} + n_{N2} \lambda^{1-\sigma})^{1/\sigma}$ despite increasing n_{N1} , but also counteracts the Southern contribution to welfare, $(n_{S2} \lambda^{1-\sigma})^{1/\sigma}$.

Proposition. If total welfare X is declining as a result of stronger patent protection, then Northern wages should be declining.

This is easy to see. Total welfare declines if only summation of $(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma}$ and $(n_{S2}\lambda^{1-\sigma})^{1/\sigma}$ declines. As n_S is monotonically increasing in stronger patent protection, $(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma}$ should be declining in such a scenario. Finally w_N should be necessarily declining, as it is the product of two declining numbers in this case.

Proposition. *If southern wages are declining with stronger patents, then Northern wages should be declining as well.*

The equations for both w_N and w_S have the common part $\left[(n_{N1} + n_{N2}\lambda^{1-\sigma})^{1/\sigma} + (n_{S2}\lambda^{1-\sigma})^{1/\sigma}\right]$. If w_S is decreasing, that common part is declining for sure since $(n_{S2}\lambda^{1-\sigma})^{1/\sigma}$ is increasing with stronger patents. If that summation is decreasing as a result of tighter IPR, then X is also decreasing. Finally from the previous proposition we know that as X declines, w_N also declines.

These last two propositions tell us that in case stronger patent protection has negative welfare effects, rather than the imitating South, North will be the first country to be negatively affected. Even though such a scenario is possible depending on initial values chosen for the model, generally it can be inferred that stronger patent protection improves the total welfare as the total variety of goods N increases .

4.2.2 Specialization

Things will be a little different in a world where there is complete specialization. This is the BC segment on equilibrium line on figure 4 and the case discussed in many product cycle models in literature. But in this particular model, stronger patents do not push more researchers to do more product innovation, unless it does not move the world economy to AB part of equilibrium where South will also start doing product innovation. In this case implementation of stricter intellectual property rights will fail to spur any new product innovation in world economy altogether. Results would be different if North had the technology to switch some of manufacturing resources to more R&D. But share of R&D in GDP has been a persistent number in developed countries, at least in short to medium run (Organisation for Economic Co-operation and Development, 2011: 165).

In a world with complete specialization, $z_1 = z_N$, $z_2 = z_S$, $n_1 = n_N$ and $n_2 = n_S$. Using the steady state flow equations $n_1(\delta + \nu) = \gamma z_N$, $n_2\delta = \kappa z_S$ like before, we obtain the number of variety of goods as follows:

$$\begin{aligned} n_1 &= \frac{\gamma_N}{\delta + \nu} z_N \\ n_2 &= \frac{\kappa}{\delta} z_S \end{aligned}$$

We can eliminate κ from our equations using the specialization equation (16) (so that ν will be the only variable that will determine final values of n_1, n_2, X, w and f). Then we get the following equations:

$$\begin{aligned} n_1 &= \frac{\gamma_N}{\delta + \nu} z_N \\ n_2 &= \frac{\nu \gamma_N}{\delta (\delta + \nu)} z_N \end{aligned} \tag{20}$$

In case of complete specialization, we will be on *SS* curve on figure 8. This time when a stronger patent system is implemented, unlike the previous case, probability of secondary innovation per researcher κ will also decline since all that patent reform do is to increase the friction variable m in the matching function, without changing number of product innovators, z_1 or process innovators z_2 (assuming patent reform is not strong enough to push economy to the zone where South will also start doing product innovation). Using equation (20) we get the total number of variety of goods:

$$N = n_1 + n_2 = \frac{\gamma_N}{\delta} z_N \tag{21}$$

It is easy to see that the total number of goods do not depend on any variables that a patent reform would affect (Namely κ and ν). In this case, a stronger patent reform will not change N , it will only alter the distribution of goods that are produced in North and South.

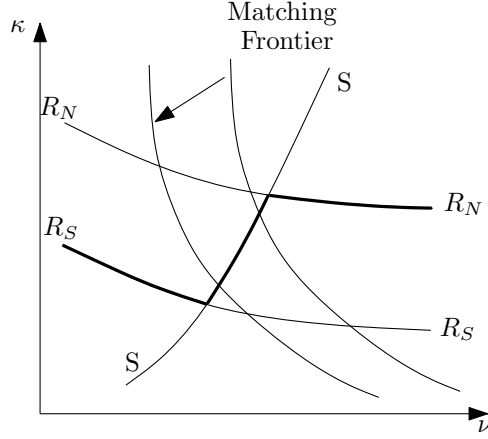


Figure 8: Stronger Patents in Open Economy

How about the welfare? In order to analyze the effects of implementation of said policies on welfare, we need to solve the equations for w_N, w_S and X . Modifying the general equilibrium equations from (17), we get:

$$\begin{aligned}
 1 - z_N &= n_1 X w_N^{-\sigma} \mu^{-\sigma} \\
 \frac{1 - z_S}{\lambda} &= n_2 X w_S^{-\sigma} \mu^{-\sigma} \lambda^{-\sigma} \\
 1 &= n_1 w_N^{1-\sigma} \mu^{1-\sigma} + n_2 w_S^{1-\sigma} \mu^{1-\sigma} \lambda^{1-\sigma}
 \end{aligned} \tag{22}$$

First two lines are manufacturing constraints for North and South. The last line comes from $P = 1$. Solving for these equations we get:

$$X = \left[n_1^{1/\sigma} (1 - z_N)^{(\sigma-1)/\sigma} + n_2^{1/\sigma} (1 - z_S)^{(\sigma-1)/\sigma} \lambda^{(1-\sigma)/\sigma} \right]^{\sigma/(\sigma-1)}$$

Finally, if we assume $z_N = z_S = z$, then we get:

$$\begin{aligned}
X &= (1 - z) \left[n_1^{1/\sigma} + n_2^{1/\sigma} \lambda^{(1-\sigma)/\sigma} \right]^{\sigma/(\sigma-1)} \\
w_N &= n_1^{1/\sigma} \left[n_1^{1/\sigma} + n_2^{1/\sigma} \lambda^{(1-\sigma)/\sigma} \right]^{1/(\sigma-1)} \frac{1}{\mu} \\
w_S &= n_2^{1/\sigma} \left[n_1^{1/\sigma} + n_2^{1/\sigma} \lambda^{(1-\sigma)/\sigma} \right]^{1/(\sigma-1)} \lambda^{(1-\sigma)/\sigma} \frac{1}{\mu}
\end{aligned} \tag{23}$$

Total expenditure X and wages w_N and w_S all depend on number of goods that countries manufacture: $n_N = n_1$ and $n_S = n_2$. From these equations we derive the terms of trade and relative wages:

$$\begin{aligned}
\frac{p_N}{p_S} &= \left(\frac{n_1}{n_2} \right)^{1/\sigma} \lambda^{-1/\sigma} \\
\frac{w_N}{w_S} &= \left(\frac{n_1}{n_2} \right)^{1/\sigma} \lambda^{(\sigma-1)/\sigma}
\end{aligned}$$

A stronger patent system will worsen the terms of trade and relative wages for South as it will increase n_1 and decrease n_2 as it can be directly inferred from these equations.

How about the level of welfare and wages? In the complete specialization zone, increase in m (*i.e.* stronger patents) decreases both probability of success for process innovators κ , and probability of being replaced for primary goods by secondary goods ν .

Proposition. *Patents have a positive effect on total welfare X , that is $\frac{\partial X}{\partial m} > 0$, iff $\nu > \lambda^{-1}$*

By solving the model we see that $\frac{\partial X}{\partial m} = 0$ iff $\nu = \lambda^{-1}$. The total welfare is an inverse U shaped function of patent protection m , and it has a maximum at $\nu = \lambda^{-1}$. A proof is provided in Appendix. Implication of that is stronger patents improve welfare only when there is more than certain level of replacement (or imitation) of primary goods: $\nu > \lambda^{-1}$. In such a case of “too much imitation”, improvement in total world welfare as a result of increasing patent protection happens because marginal contributions of gain from welfare improvements in the North is higher than the marginal losses from the decline of welfare in the South.

Of course we have no guarantee for $\nu = \lambda^{-1}$ taking place on the interval BC on figure 4 where full specialization equilibrium occurs. It may lie to the right or left of BC interval depending on initial parameters. This uncertainty will have different policy implications for world welfare.

Southern wages on the other hand will improve with stronger patents, that is $\frac{\partial w_S}{\partial m} > 0$, if there is even more replacement of primary goods compared to the case for X just discussed: $\frac{\partial w_S}{\partial m} > 0$ iff $\nu > \delta(\sigma - 1) + \lambda^{(\sigma-1)/\sigma} \nu^{1/\sigma} \sigma$. Here we need higher values of ν compared to previous case to justify stronger patents for South; w_S is maximized at a higher value of ν compared to X .¹² This is a more unlikely scenario to realize compared to the stronger patents being good for X , it will only happen when Northern market is so small that an improvement there will have a positive contribution to southern wages w_S as a result of increase in exports.

Finally stronger patents will improve northern wages, $\frac{\partial w_N}{\partial m} > 0$ as long as replacement (imitation) rate (ν) is not too low: $\frac{\partial w_N}{\partial m} > 0$ iff $\lambda \nu^{3/2} (\sigma - 1) + \delta \nu \sigma - \lambda \nu^{1/\sigma} \delta > 0$. This is a scenario that is more unlikely to realize compared to previous scenarios to begin with. Wages in north will improve with less patents in the case of “too low ν ” only because gains from exports to south will improve northern wages despite the loss of manufacturing to south in case of an extremely impoverished south.

These results are illustrated on figure 9. We have three cut points for ν , and to the right of each cut point, indicated variable will improve as a result of stronger patents¹³. Between A and C , patent reforms will improve wages in North at the expense of Southern wages. But between B and C , welfare of world economy X will improve as South is worse-off. In this case, a compensation from North to South might be a proper way to increase world welfare while making patents stronger.

Initial parameters are important as welfare and wage functions are non monothonic in degree of patent protection. Here the welfare analysis has nothing to do with more product innovation, but with distribution of it.

¹²Which is in fact equivalent to saying $\frac{\partial w_S}{\partial m} = 0$ iff $\nu = \delta(\sigma - 1) + \lambda^{(\sigma-1)/\sigma} \nu^{1/\sigma} \sigma$, w_s has a maximum at $\nu = \delta(\sigma - 1) + \lambda^{(\sigma-1)/\sigma} \nu^{1/\sigma} \sigma$. When we compare the critical points where $\frac{\partial w_S}{\partial m} = 0$ and $\frac{\partial X}{\partial m} = 0$, we find that it is higher for w_S .

¹³Those cut points indicate where welfare or wages maximized, *e.g.* X is maximized at B on figure 9

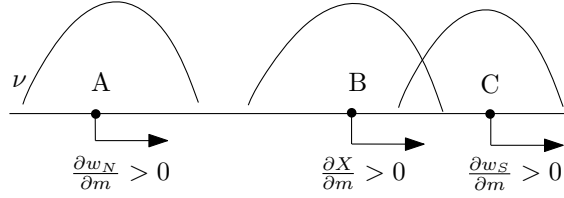


Figure 9: Effect of Patent Reforms on Welfare

5 Subsidies

Many developing countries are trying to embrace a more innovative economy, and what they mean by that is they would like to do more product innovation. Policy makers are trying to implement policies that divert more resources to product innovation, even though wisdom and success of such policies are increasingly being questioned (Breznitz and Murphree (2011)). This model may explain the pitfalls a policy that makes product innovation a priority in a country that specializes in process innovation may face.

Suppose that government in South decides to subsidize product innovation only. They announce that they will pay a certain share of research and development expenditure that is made for product innovation. We will indicate the mentioned fraction with u , where $0 \leq u \leq 1$. Subsidies will be funded through lump-sum taxes. As a result of such a selective subsidy, cost of producing a blueprint for a primary product will be $F_{S1} = \frac{(1-u)f_S}{\gamma_S}$, whereas the cost of process innovation will stay the same as before, $F_{S2} = \frac{f_S}{\kappa}$.

This modification of the system will alter the Free Entry Condition for South. Relative cost of product innovation declines, therefore we need to modify our free entry condition RR_S :

$$RR_S = \frac{\lambda^{\sigma-1} (r + \delta) \gamma_S}{\kappa (r + \nu + \delta) (1 - u)}$$

This means an upward shift of RR_S curve. Matching frontier will not be affected by such a policy. Suppose that we are at an equilibrium where South is specialized on Process innovation, whereas North does both kinds of innovation, namely we are on part AB on equilibrium line in

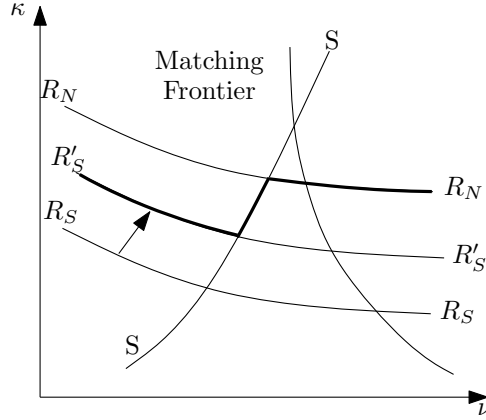


Figure 10: Subsidies in an Open Economy

figure 4.

What figure 10 tells us that subsidies may not have any affect on what kind of research being done in South, especially when North is doing both kinds of research¹⁴. It is possible that it may push South to do both types of innovation when there is complete specialization of research, but even then this will come at the expense of welfare loss from such subsidies¹⁵. As a result we can say that not only that subsidies targeted at product innovation may not work at all, even when they do their welfare effects will not be clear cut.

6 Foreign direct investment

It is very hard to make an analysis on international patent agreements without taking Foreign Direct Investment into account. Many countries that are good at process innovations, innovations that make it possible to produce goods cheaper, are also the countries that are big recipients of foreign direct investment. One of the relevant issue here is the fact that many companies have been designing their products in one country and producing the said product in another country. There are many factors affecting foreign direct investment like political stability, institutions, geography,

¹⁴I assume South will not be able to subsidize to the point RR_S lie above RR_N

¹⁵Size of consumer expenditure in South will be $X_S - Taxes$, which is indirect utility as indicated in (6). Higher taxes will mean a loss of welfare.

and there exists complicated scenarios involving creation of sophisticated supply chains requiring subsidiaries in other countries. These are beyond the scope of this paper. But we can look at the effects of an international patent reform on wages of workers, profits and investment decisions of companies that operate on both national and multinational level within the given framework.

First of all, the same framework we have created so far will apply here, but we need to make some minor modifications. We will look into a case where companies in North can innovate in North but have the option to choose between producing in either North or South. As a result we will split the n_{Ni} into two more categories based on where the goods are being produced, where i indicates if good is primary or secondary. Some northern companies will be national companies, designing and producing in North alone. They will be producing n_{NNi} variety of goods. And some northern companies will be multinational. They will design their products in North but will be producing in South. They will produce n_{NSi} variety of goods.

The process of finding the equilibrium flow rates (κ, ν) is same as before, and figure (5) still applies. After finding the equilibrium (κ, ν) , we can proceed and find the equilibrium allocation of goods and wages.

We will look into the case where countries are completely specialized. As a result North will do primary innovation whereas South will do process innovation. But when it comes to production, South will be producing both types of goods whereas North will specialize on producing Primary goods. Because of specialization we have the following conditions:

$$n_{N1} = n_1 = n_N = n_{NN1} + n_{NS1}$$

$$n_{S2} = n_2 = n_S$$

We will look into the case where without Foreign Direct Investment, wages in North would be higher. Otherwise there would be no investment in South by foreign companies. Thanks to Foreign Direct Investment, wages in North and South will equalize, hence $w_N = w_S = w$.

Since all the primary innovation is being done in North, equation (21) for total number of goods

will continue to hold as before, $N = n_1 + n_2 = \frac{\gamma_N}{\delta} z_N$. Total number of goods depend only on how many innovators are allocated to primary allocation and all the primary innovation is being done in North in complete specialization case. Likewise the equations for $n_1 = n_N$ and $n_2 = n_S$ from equation (20) applies here as well:

$$n_1 = \frac{\gamma_N}{\delta + \nu} z_N, \quad n_2 = \frac{\nu \gamma_N}{\delta (\delta + \nu)} z_N$$

Prices for primary goods is indicated as p_1 and p_2 for secondary goods. In this setting, prices do not depend on where goods are originated from, all what matters is if they are primary or secondary goods. As described in equation (11), we find that $p_1 = \mu w$ and $p_2 = \mu \lambda w$ as a result of monopolies maximizing their profits. Respective demand functions are derived as $c_j = X p_j^{-\sigma}$ for each good j . It is $c_1 = X(\mu w)^{-\sigma}$ for primary goods, and $c_2 = X(\mu \lambda w)^{-\sigma}$ for secondary goods.

Finally, the solution to equilibrium in this economy will depend on following three equations:

$$\begin{aligned} 1 - z_N &= n_{NN1} c_1 \\ 1 - z_S &= n_{NS1} c_1 \lambda + n_{S2} c_2 \\ 1 &= n_{NN1} p_1 + n_{NS1} p_1 + n_{S2} p_2 \end{aligned} \tag{24}$$

First two equations are resource constraints for production in North and South. Last line is the condition that price index is equal to one.

Using $p_1 = \mu w$ and $p_2 = \mu \lambda w$, we can express last line of equation (24) as:

$$(\mu w)^{1-\sigma} (n_{NN1} + n_{NS1} + n_{S2} \lambda^{1-\sigma}) = 1$$

From this equation we can derive the equation for w :

$$w = (n_{NN1} + n_{NS1} + n_{S2} \lambda^{1-\sigma})^{1/(\sigma-1)} \frac{1}{\mu} \tag{25}$$

The effects of implementation of a stronger intellectual property rights scheme is easier to deduct in case of foreign direct investment. As before, a stronger patent system will not increase the total number of goods as this number depends on the number of innovators working for primary innovation and number of product innovators simply equals to number of researchers in North. But such a policy will decrease the flow rate κ for southern innovators as shown on figure 8, hence increasing the number of primary goods while decreasing the number of secondary goods equally. That means number of primary goods $n_{N1} = n_{NN1} + n_{NS1}$ will increase but number of secondary goods n_{S2} will decrease. Since $\lambda^{1-\sigma} > 1$, implication of this is a decline in worldwide wages as the expression in right hand side of equation (25) decreases.

Next we will look into how decisions of northern companies on location of their production facilities is affected by such a policy reform. Specifically we want to understand how n_{NN1} and n_{NS1} are affected by stronger patent reforms.

Once more we will refer to equation (24), but first two lines. To keep things simpler, we will assume $z_N = z_S = z$ as before. Then using price equations $p_1 = \mu w$ and $p_2 = \mu \lambda w$ and corresponding demand functions $c_1 = X (\mu w)^{-\sigma}$ and $c_2 = X (\mu w \lambda)^{-\sigma}$, we get:

$$\begin{aligned} 1 - z &= X (\mu w)^{-\sigma} n_{NN1} \\ 1 - z &= X (\mu w)^{-\sigma} (n_{NS1} + n_{S2} \lambda^{1-\sigma}) \end{aligned}$$

We can easily derive the condition:

$$n_{NN1} = n_{NS1} + n_{S2} \lambda^{1-\sigma}$$

This equation tells us that everything else equal, there is a positive correlation between how many goods being produced in North n_{NN1} and number of goods being produced in South, n_{S2} . Finally using the fact that $n_N = n_{NN1} + n_{NS1}$, we find the how the distribution for northern

companies' production will be across countries:

$$n_{NS1} = \frac{n_N - n_{S2}\lambda^{1-\sigma}}{2}$$

$$n_{NN1} = \frac{n_N + n_{S2}\lambda^{1-\sigma}}{2}$$

As indicated before, values for n_N and $n_{S2} = n_S$ can be found from equation (20) as $n_N = \frac{\gamma_N}{\delta+\nu}z_N$ and $n_{S2} = \frac{\nu\gamma_N}{\delta(\delta+\nu)}z_N$.¹⁶ These two equations tell us that as number of goods being produced by northern companies (n_N) increase and number of goods produced by southern companies (n_S) decline, northern companies will shift their production more to South (n_{NS1}) while there will be less and less variety of goods (n_{NN1}) being produced in North.

A stronger patent system will exactly do that: it will increase n_N while decreasing n_S . The results will be same as described above. More northern companies will shift their production to South. This result is parallel to findings by Branstetter et al. (2006) and Bilir (2011)¹⁷. They demonstrate that producers in USA increase their foreign direct investment as developing countries implement stricter patent laws and they are protected more against imitation in these countries. The mechanism for rising levels of FDI as a result of stronger patent laws is a little different here. We get an increase in foreign direct investment by Northern producers despite the fact that the probability of being replaced by a southern producer is not affected by where you locate the production facilities of your goods. The reason for the rise in the level of foreign direct investment in this model is loss of manufacturing in the South as a result of stronger patent laws. Strict IPRs will limit the rate of imitation in the South, therefore causing a decline in the level of manufacturing and wage level in the South. This will cause the Northern companies to move their manufacturing operations to the South, and as a result wages in the North will also be driven down.

¹⁶Since we can not have negative number of goods being produced in one country, I will make the assumption $n_N > n_S\lambda^{1-\sigma}$ to begin with. In complete specialization case, I will assume that there are sufficiently high number of goods produced by northern companies relative to goods produced by southern companies.

¹⁷Bilir (2011) finds that patents matter more for products that has long product life cycles, products that become obsolete less frequently. In our model, all goods have the same rate of being obsolete, δ .

7 Conclusion

In this paper I show how the specialization patterns in R&D arise between countries. Previous product cycle literature have taken the difference between countries as given, by assuming developed countries doing the novel product innovation while developing countries just imitating them. I first take R&D as a decision of choosing between conducting novel-product innovation or follow-up process innovation, a decision that is available to residents of both developed and developing nations. Then I show that different equilibria other than complete specialization of countries is possible. Even though developed countries have comparative advantage in novel product innovation and developing countries have comparative advantage in follow-up process innovation, there are equilibria where countries do not specialize and conduct both types of research at the same time. The only catch is that both developed and developing countries can not conduct both types of R&D simultaneously. One group of countries has to specialize on what they have comparative advantage at. The implication of this result is that, in the case of developed countries conducting both kinds of R&D, developing countries will not be conducting any novel-product innovation since it will not be profitable to do so.

Policy implications of existence of diverse equilibria are many. First of all, if developed nations are conducting both product and process types of R&D, stronger IPRs will not decrease the rate developing countries imitate. In the case world economy is completely specialized like it is in product cycle literature, stronger IPRs may improve the world wide product innovation levels only if they are drastic enough to push South to commit resources to product innovation; otherwise their effects will only be distributive. Stronger IPRs in case of complete specialization will worsen the terms of trade for developing countries, and will be more likely to hurt these countries more. In contrast, in case of incomplete specialization, stronger IPRs will hurt developing countries only if they hurt developed countries first. Lastly, subsidies to product innovation in developing countries will not work in case of incomplete specialization where developed nations are conducting both

kinds of R&D¹⁸.

Finally I show how foreign direct investment is affected by stronger IPRs policies. If developed countries can set up production facilities in developing nations, their investment levels in foreign countries will respond positively to stronger IPRs in case countries specialize in R&D they conduct. Worldwide wages and welfare will be negatively affected by stronger IPRs laws.

¹⁸Assuming subsidy levels can not be high enough to provide comparative advantage in product innovation to developing nations

A Optimal Patents in Closed Economy

Matching frontier equation and free entry condition give us the following conditions:

$$(m\kappa)^{1/(1-\alpha)} = (m\nu)^{1/(-\alpha)}$$

$$1 = \frac{\lambda^{\sigma-1} (r + \delta) \gamma}{\kappa (r + \nu + \delta)}$$

These two allow us to solve for (κ, ν) . Then we get the following condition from flow rates (8):

$$\kappa = \frac{\nu \gamma}{\delta + \nu} \frac{z_1}{z_2} \quad (26)$$

Using equation (26) and $z_1 + z_2 = z$ we get:

$$z_1 = \frac{\kappa(\delta + \nu)}{\kappa(\delta + \nu) + \nu\gamma} z, \quad z_2 = \frac{\nu\gamma}{\kappa(\delta + \nu) + \nu\gamma} z \quad (27)$$

Using steady state flow equations $n_1(\delta + \nu) = \gamma z_1$, $n_2\delta = \kappa z_2$ and equation (27), we obtain the values for n_1 and n_2 :

$$n_1 = \frac{\kappa\gamma}{\kappa(\delta + \nu) + \nu\gamma} z, \quad n_2 = \frac{\kappa\nu\gamma}{\delta(\kappa(\delta + \nu) + \nu\gamma)} z$$

$$N = \frac{\kappa\gamma(\delta + \nu)}{\delta(\kappa(\delta + \nu) + \nu\gamma)} z$$

Using resource constraint and price normalization we get:

$$1 - z = n_1 c_1 + n_2 c_2 \lambda$$

$$P = 1 = p_1 n_1 + p_2 n_2$$

Solving for this equations and inserting appropriate price and demand functions give us the

solution for manufacturing wages and welfare in terms of n_1 and n_2 :

$$w = (n_1 + n_2 \lambda^{1-\sigma})^{\frac{1}{\sigma-1}} \frac{1}{\mu}$$

$$X = (n_1 + n_2 \lambda^{1-\sigma})^{\frac{1}{\sigma-1}} (1 - z)$$

Substituting for n_1 and n_2 we can find the complete closed solution for X as follows:

$$X = (1 - z) \mu \left[\frac{(\delta + \nu \lambda^{1-\sigma}) \gamma \kappa}{\delta (\kappa (\delta + \nu) + \nu \gamma)} z \right]^{\frac{1}{\sigma-1}}$$

We know that in a closed economy, implementation of stronger patents (an increase in m in matching equation (7)) result in a decline in ν and increase in κ . This can be seen from figure 6. Hence we can say

$$\frac{\partial \nu}{\partial m} < 0 \text{ and } \frac{\partial \kappa}{\partial m} > 0$$

Then taking the derivative of X wrt m :

$$\frac{\partial X}{\partial m} = \frac{\partial X}{\partial \nu} \frac{\partial \nu}{\partial m} + \frac{\partial X}{\partial \kappa} \frac{\partial \kappa}{\partial m}$$

Taking these derivatives, we get $\frac{\partial X}{\partial \kappa} > 0 \forall (\nu, \kappa) > 0$. Then when $\frac{\partial X}{\partial \nu} < 0$, we know for sure $\frac{\partial X}{\partial m} > 0$. We get the following condition when we take the derivative:

$$\frac{\partial X}{\partial \nu} > 0 \text{ iff } \kappa > \frac{\gamma}{(\lambda^{1-\sigma} - 1)}$$

If this condition holds, we know for sure patents will positively affect welfare. Otherwise effects of a patent policy will be ambiguous.

B Optimal Patents in Open Economy

B.1 Incomplete Specialization

We are looking at the case where North is conducting both kinds of research. Matching frontier equation and free entry condition for North give us the following conditions:

$$(m\kappa)^{1/(1-\alpha)} = (m\nu)^{1/(-\alpha)}$$

$$1 = \frac{\lambda^{\sigma-1} (r + \delta) \gamma_N}{\kappa (r + \nu + \delta)}$$

Using flow equations $\kappa z_2 = \nu n_1$, $n_1 (\delta + \nu) = \gamma z_1$ and $z_1 + z_2 = z_N + z_S$ we find:

$$z_1 = z_{N1} = \frac{\kappa (\delta + \nu) (z_N + z_S)}{\kappa (\delta + \nu) + \nu \gamma_N}, \quad z_2 = \frac{\nu \gamma_N (z_N + z_S)}{\kappa (\delta + \nu) + \nu \gamma_N}$$

To simplify things, we will assume $z_N = z_S = z$. We can find the allocation of secondary researchers between South and North as follows:

$$z_{N2} = z - z_{N1} = \frac{z (\nu \gamma_N - \kappa (\delta + \nu))}{\kappa (\delta + \nu) + \nu \gamma_N}, \quad z_{S2} = z$$

Finally we can derive the values for n_{N1}, n_{N2}, n_{S2} and N (total number of goods) using distribution of researchers and flow equations:

$$n_1 = n_{N1} = \frac{\gamma_N z_1}{\delta + \nu} = \frac{\kappa \gamma_N 2z}{\kappa (\delta + \nu) + \nu \gamma_N}, \quad n_2 = \frac{\kappa z_2}{\delta} = \frac{\kappa \nu \gamma_N 2z}{\delta (\kappa (\delta + \nu) + \nu \gamma_N)}$$

$$n_{S2} = \frac{\kappa z_{S2}}{\delta}, \quad n_{N2} = n_{S2} = \frac{\kappa z_{N2}}{\delta} = \frac{\kappa z (\nu \gamma_N - \kappa (\delta + \nu))}{\delta (\kappa (\delta + \nu) + \nu \gamma_N)}$$

Using resource constraints for both North and South manufacturing and price normalization

equation we get the following equations for manufacturing wages w and welfare X :

$$\begin{aligned}
1 - z_S &= n_{S2} X \lambda^{1-\sigma} (\mu w_S)^{-\sigma} \\
1 - z_N &= n_{N1} X (\mu w_N)^{-\sigma} + n_{N2} X \lambda^{1-\sigma} (\mu w_N)^{-\sigma} \\
1 &= (\mu w_N)^{1-\sigma} n_{N1} + (\mu \lambda w_N)^{1-\sigma} n_{N2} + (\mu \lambda w_S)^{1-\sigma} n_{S2}
\end{aligned}$$

Solving for wages and welfare we find:

$$\begin{aligned}
X &= (1 - z) \left[(n_{N1} + n_{N2} \lambda^{1-\sigma})^{1/\sigma} + (n_{S2} \lambda^{1-\sigma})^{1/\sigma} \right]^{\sigma/(\sigma-1)} \\
w_N &= \left[(n_{N1} + n_{N2} \lambda^{1-\sigma})^{1/\sigma} + (n_{S2} \lambda^{1-\sigma})^{1/\sigma} \right]^{1/(\sigma-1)} (n_{N1} + n_{N2} \lambda^{1-\sigma})^{1/\sigma} \\
w_S &= \left[(n_{N1} + n_{N2} \lambda^{1-\sigma})^{1/\sigma} + (n_{S2} \lambda^{1-\sigma})^{1/\sigma} \right]^{1/(\sigma-1)} (n_{S2} \lambda^{1-\sigma})^{1/\sigma}
\end{aligned}$$

Implementation of a stronger patent reform (increasing m) will result in a decline in ν but an increase in κ . Therefore we have a similar case as we had for Closed Economy:

$$\frac{\partial \nu}{\partial m} < 0 \text{ and } \frac{\partial \kappa}{\partial m} > 0$$

As a result of stricter IPRs, we will have North committing more resources on primary innovation. South will continue on committing all of its resources on process innovation. As a result we have:

$$\begin{aligned}
\frac{\partial n_{N1}}{\partial m} &= \frac{\partial n_{N1}}{\partial \nu} \frac{\partial \nu}{\partial m} + \frac{\partial n_{N1}}{\partial \kappa} \frac{\partial \kappa}{\partial m} > 0 \\
\frac{\partial n_{N2}}{\partial m} &= \frac{\partial n_{N2}}{\partial \nu} \frac{\partial \nu}{\partial m} + \frac{\partial n_{N2}}{\partial \kappa} \frac{\partial \kappa}{\partial m} < 0 \\
\frac{\partial n_{S2}}{\partial m} &= \frac{\partial n_{S2}}{\partial \nu} \frac{\partial \nu}{\partial m} + \frac{\partial n_{S2}}{\partial \kappa} \frac{\partial \kappa}{\partial m} > 0
\end{aligned}$$

Finally going the same route we find that N is an increasing with stronger patents. $n_2 = n_{N2} + n_{S2}$ is a inverse u shaped function of patent protection. n_2 is maximized when $\nu^2 = \delta \lambda^{1-\sigma} (1 + \delta)$.

B.2 Complete Specialization

We get the equilibrium values for (ν, κ) from matching function and Specialization curves:

$$(m\kappa)^{1/(1-\alpha)} = (m\nu)^{1/(-\alpha)}$$

$$\kappa = \frac{\nu\gamma_N}{\delta + \nu} \frac{z_N}{z_S}$$

We know that $z_1 = z_N$ and $z_2 = z_S$. From equation (20) we get the values for n_1 and n_2 :

$$n_1 = \frac{\gamma_N}{\delta + \nu} z_N$$

$$n_2 = \frac{\nu\gamma_N}{\delta(\delta + \nu)} z_N$$

Inserting those values into equation (23) will give us the solution this model:

$$X = (1 - z) \left(\frac{(\gamma_N z)^{1/\sigma} \left(\delta + \nu^{1/\sigma} \lambda^{\frac{1-\sigma}{\sigma}} \right)}{((\delta + \nu) \delta)^{1/\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$\mu w_N = \left(\frac{\gamma_N z}{\delta + \nu} \right)^{1/\sigma} \left(\frac{(\gamma_N z)^{1/\sigma} \left(\delta + \nu^{1/\sigma} \lambda^{\frac{1-\sigma}{\sigma}} \right)}{((\delta + \nu) \delta)^{1/\sigma}} \right)^{\frac{1}{\sigma-1}}$$

$$\mu w_S = \left(\frac{\nu\gamma_N z}{(\delta + \nu)\delta} \right)^{1/\sigma} \left(\frac{(\gamma_N z)^{1/\sigma} \left(\delta + \nu^{1/\sigma} \lambda^{\frac{1-\sigma}{\sigma}} \right)}{((\delta + \nu) \delta)^{1/\sigma}} \right)^{\frac{1}{\sigma-1}}$$

We know that $\frac{\partial \nu}{\partial m} < 0$ from figure 8.

After taking the appropriate derivatives we find the following conditions:

- $\frac{\partial X}{\partial m} = 0$ when $\nu = \lambda^{-1}$, and second derivative is negative.
- $\frac{\partial w_S}{\partial m} = 0$ when $\nu > \delta(\sigma - 1) + \lambda^{(\sigma-1)/\sigma} \nu^{1/\sigma} \sigma$, and second derivative is negative
- $\frac{\partial w_N}{\partial m} = 0$ when $\lambda \nu^{3/2} (\sigma - 1) + \delta \nu \sigma - \lambda \nu^{1/\sigma} \delta > 0$, and second derivative is negative

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